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Farming Hybrid Poplar for Food and Fibre:

An Exploratory Study of the Seasonal Above-Ground Biomass

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by

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The oven-dry biomass and protein content of leaf, unlignified, bark and wood tissues of five hybrid poplar clones grown in Southern Ontario were analysed at biweekly intervals between July and October 1974. Crude protein levels per gram of each tissue decreased with time but production rate of protein per stool remained approximately constant until leaf fall, due to the compensating effect of increasing biomass accumulation. Protein quality, based on essential amino acid profiles, compared favourably with many farm crops. Several harvesting options, based on different degrees of product integration, are discussed.

INTRODUCTION

Short rotation forestry will probably be the key to meeting the increasing demand of world markets for many forest products. A promising system is offered by intensive cultivation of selected, high-yielding poplars on the better sites available for timber production. Previous studies have indicated the high production and fibre quality potential of closely-spaced one- and two-year-old hybrid poplar coppices grown in so-called "mini-rotation" (Zufa and Balatinecz 1971, Anderson and Zsuffa 1975).

The forecasted shortages of world food production and Siren *et al's* (1970) report on the protein content of poplars prompted us to expand the mini-rotation concept to an integrated multi-product system of "poplar-farming", in which the entire aerial biomass is cropped for fibre, food and other diverse physical and chemical products.

The following report will indicate some of the preliminary results of this investigation.

METHODS

In the spring of 1972, stools of five clones (Table 1) were established at a spacing of 0.45 x 1.22 m in a nursery area at Orono, Ontario (44°N, 78° 30' W). The site was characterized by a clay-loam soil of poor drainage. Sprout growth was harvested for cuttings in 1972 and 1973.

TABLE 1 Hybrid poplar clones analysed

DN1	*P.* x *euramericana* cl. "Allenstein", Germany
DN17	*P.* x *euramericana* cl. "Robusta", France
DN20	*P.* x *euramericana* cl. "I-61/59", Italy
I-45/51	*P.* x *euramericana* cl. "I-45/51", Italy
GA88	*P. grandidentata* x *alba*, Maple, Canada

In 1974, the entire living sprout growth of one preselected stool of each clone was collected at biweekly intervals between July 2 and October 8. The individual sprouts were measured for length and basal caliper and were segregated into leaf, unlignified (soft, upper tissue) and lignified (bark and wood) tissues. Fresh and oven-dry weights were determined and bark/wood ratio estimates calculated. Total nitrogen (Kjeldahl), and crude

protein (N x 6.25) were determined on composite subsamples of each of the four types of tissues. Amino acid composition (Technicon auto-analyzer) was determined on hydrolyzed leaf tissue on August 13 samples and on both leaf and bark tissues on October 8 samples[1].

RESULTS

The seasonal growth (of total above-ground oven-dry biomass) per stool of the five clones is illustrated in Figure 1. The decrease in yield after September 24 was due to leaf senescence and shedding, except for clone DN1, in which those processes occurred later. The growth pattern of the only aspen clone, GA88 (a *Leuce* Duby hybrid) was exceptional. In mid-August, when most of the clones of euramerican hybrid origin had completed two-thirds of their maximum growth, clone GA88 accelerated, increasing its biomass by 300% in the late summer to a maximum of 1.3 kg/stool. By comparison, I-45/51, the best of the euramerican clones in the test, produced a maximum yield of only 0.6 kg/stool. The superiority of GA88 was due to better average total sprout height growth (1.63 m for GA88 compared to 1.10 m for I-45/51) and to a much larger number of sprouts per stool (an average of 31 sprouts for GA88 compared to 9 sprouts for I-45/51 in mid-August).

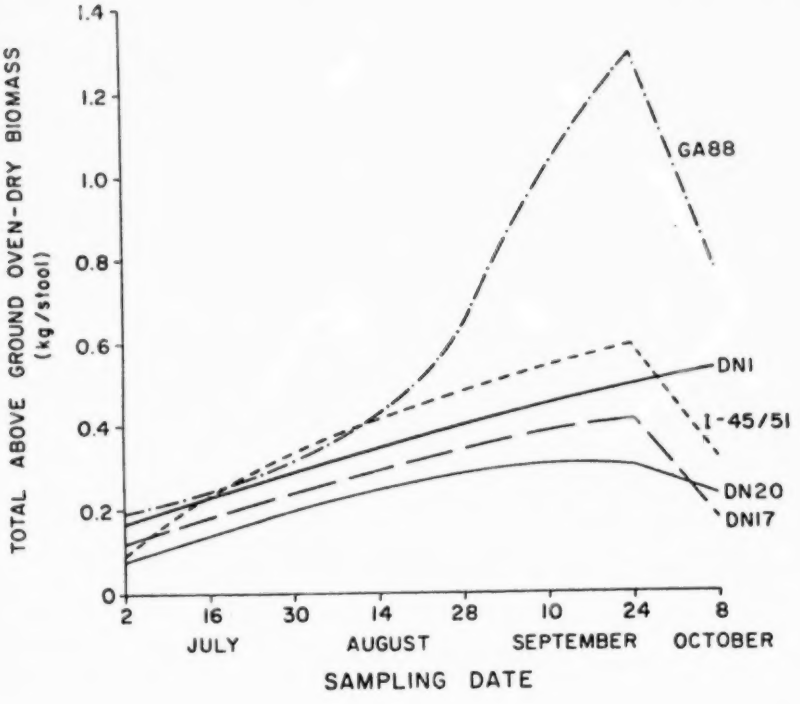
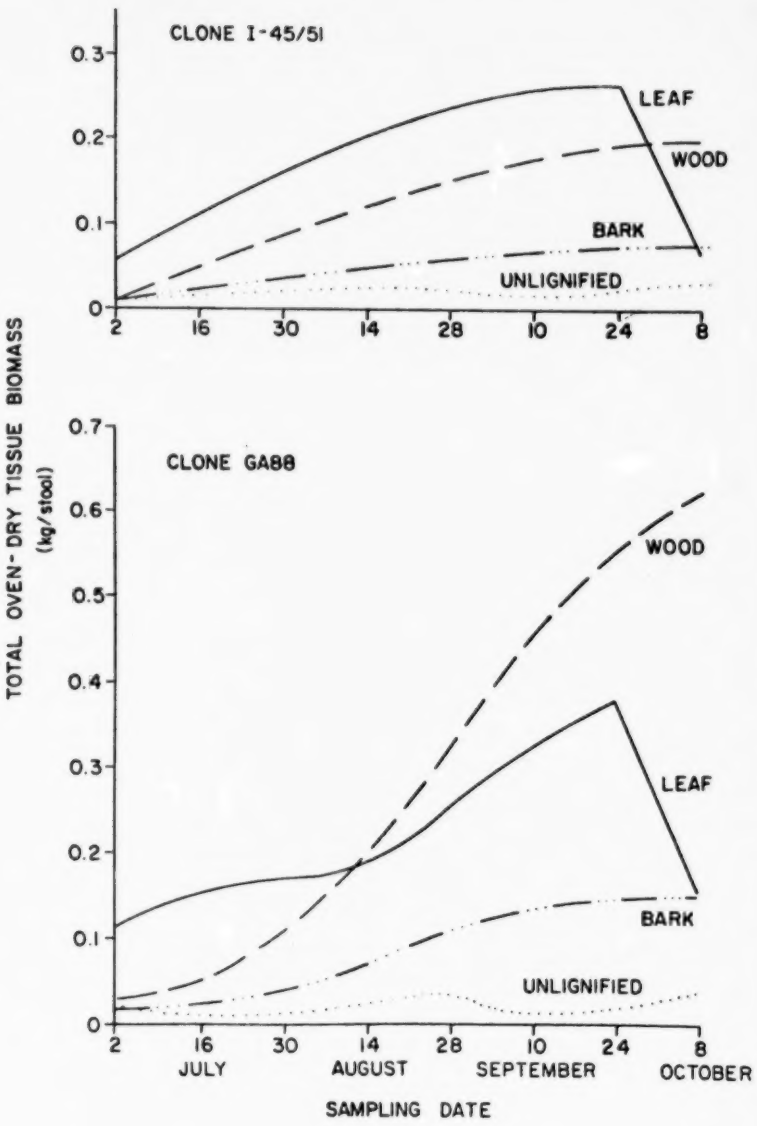


Figure 1 Average total above-ground oven-dry biomass of five hybrid poplar clones sampled bi-weekly.

1 Unpublished report, Ontario Research Foundation, December, 1974, on file.

Figure 2 Average total above-ground oven-dry biomass of leaf, unlignified, bark and wood tissue of clone I-45/51 and clone GA88 sampled biweekly.



The development of tissue components (oven-dry leaves, unlignified, bark, and wood) is shown in Figure 2 for the two fastest growing clones (I-45/51 and GA88). For clone I-45/51 (Fig. 2a), the contribution throughout the growing season of leaves to total stool biomass was about 50%. Other tissues also maintained roughly proportional amounts (wood 30-35%, bark 13%, and unlignified 4-7%). In contrast, clone GA88 (Fig. 2b) showed a very high contribution of leaf biomass in early summer, proportionally similar yields of leaf and wood by mid-August, and a sharp increase in wood tissue by late summer. By September 24, wood contributed 52% of biomass, and leaves only 35%. The proportion of bark and unlignified tissue remained approximately the same over the growing season (at 12% and 2% respectively).

Intrinsic nitrogen (ie. nitrogen content per unit mass) and corresponding crude protein contents of the four tissue types sampled on July 2 are shown in Figure 3. On the average, maximum protein levels are found in leaves (22% of oven-dry weight) followed by unlignified tissue (18%), bark (11%) and finally wood (6%). There is some consistent variation among clones, with I-45/51 being above average and DN20 below average for most tissues. The least degree of clonal variation occurred in leaf tissue.

The crude protein content per gram of tissue decreased rapidly towards August, after which it was relatively stable. Figure 4 illustrates this for leaf and unlignified tissue for clones I-45/51 and GA88. The difference in protein content between the tissue types of each clone increased as the season progressed, with leaf tissue tending to stabilize somewhat earlier and maintain relatively higher protein levels than unlignified tissue. The higher protein level in late summer of GA88 compared to I-45/51 was related to its growth surge which occurred at that time. Limited sampling suggested that similar but quantitatively lower trends existed in bark and wood tissues as well.

Although the protein content per gram of tissue decreases as the growing season progresses, the total yields of protein per stool may increase if the biomass accumulates at a higher rate. For clone I-45/51 the decrease in protein tended to be offset by accumulating dry matter such that, except for early summer and late fall, the production rate of crude protein was relatively constant (Fig. 5). On the other hand, for GA88, the late season growth surge increased the protein yield considerably at a time when intrinsic protein content was relatively low.

The quality of any protein source is evaluated on the basis of its amino acid (AA) composition. Total amino acids on the average accounted

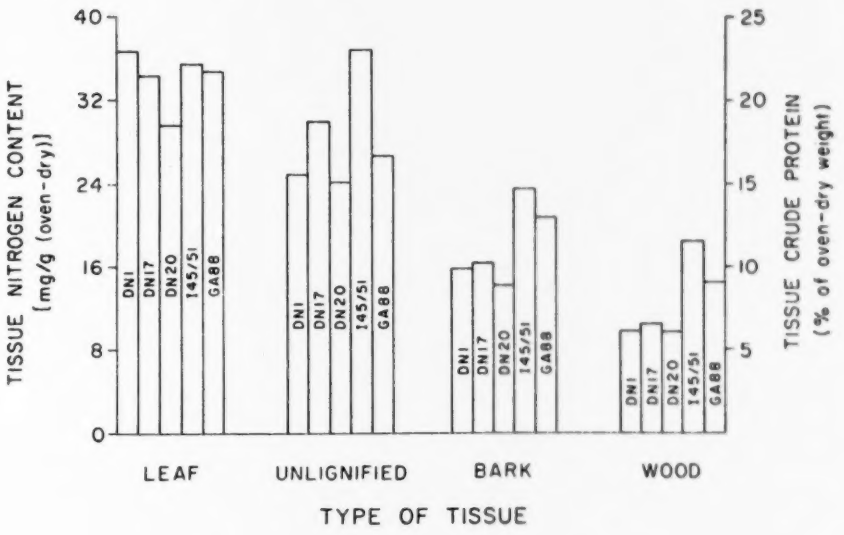
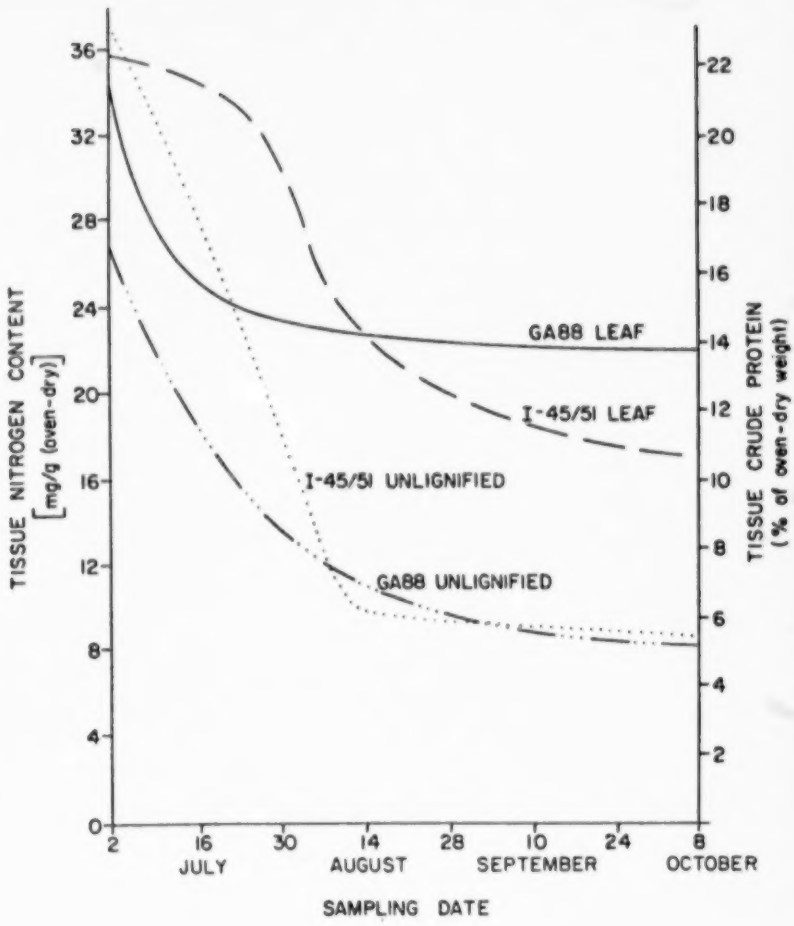


Figure 3 Average nitrogen and crude protein content of leaf, unlignified, bark, and wood tissue of five hybrid poplar clones sampled on July 2.

Figure 4 Average nitrogen and crude protein content of leaf and unlignified tissue of clones I-45/51 and GA88 sampled biweekly.



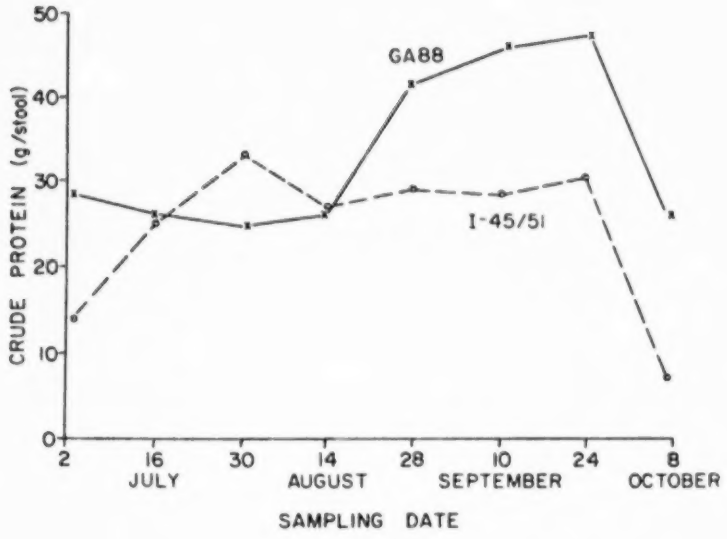


Figure 5 Average crude protein yield per stool (leaf and unlignified tissue only) of clones I-45/51 and GA88 sampled biweekly.

for 91.7% and 90.2% of apparent (crude) protein in leaves in August and October respectively. Clonal variation was about 5% at both dates. Of special significance is the concentration of the eight amino acids known to be nutritionally essential for human development. Table 2 summarizes the total content of these "essential amino acids" (EAA) in the leaves of the five clones collected on August 13 and October 8, and in the bark of these clones on October 8. Tryptophan was degraded during hydrolysis and is excluded.

On a total-protein basis, there was only a small decrease (about 2 percentage points) in average EAA concentration between August and October. On the basis of dry weight, however, protein quality of leaves showed a proportionately greater change, decreasing from 5.2% to 4.4% between August and October. Just prior to leaf-fall, bark had about 60% of the EAA content of attached leaves. Clonal variation in leaf EAA was about 20% with DN20 being better and I-45/51 poorer than average. This is in direct contrast to the pattern of crude protein content for these clones on July 2 (Fig. 3). Clone GA88 showed a slight increase in protein quality (dry weight basis) between August and October, perhaps due to its late season growth surge and resultant abundance of physiologically active tissue. Conversely, DN1, which held its leaves for an extended period in October, showed a significant decrease in protein quality with time. Perhaps DN1 retained leaves from which many nutrients had already been mobilized and translocated. This might also explain the particularly high EAA content (total protein basis) of the bark of DN1 in October.

Certain of the EAA compounds are of special interest due to their general scarcity in farm crops. Table 3 shows the EAA profiles of the leaves of I-45/51 and GA88 collected in August and October. It can be seen that, at both dates, GA88 had higher levels of all EAA than I-45/51. The decrease in EAA with time for I-45/51 was due mainly to reductions in leucine and methionine, although the overall levels of the latter important AA were probably underestimated due to process-degradation. The observed increase over time for GA88 is reflected by increases in valine and lysine. The latter compound is very significant nutritionally since it is characteristically scarce in most cereal crops.

TABLE 2 Essential amino acid contents (tryptophan excluded) of leaf and bark tissue of five hybrid poplar clones sampled in August and October

Clone	August 13/74		October 8/74			
	Leaves		Leaves		Bark	
	% of protein	% of dry weight	% of protein	% of dry weight	% of protein	% of dry weight
I-45/51	35.8	4.8	34.3	3.7	33.4	2.2
DN17	35.5	4.4	34.7	3.7	35.5	2.8
DN20	41.9	5.4	36.8	4.4	35.7	2.4
DN1	38.6	5.8	35.8	4.2	40.2	2.5
GA88	37.6	5.8	36.8	6.0	32.9	3.3
Average	37.9	5.2	35.9	4.4	35.5	2.6

TABLE 3 Essential amino acid profiles (tryptophan excluded) of leaf tissue of clones I-45/51 and GA88 sampled on August 13 and October 8

Essential amino acid	I-45/51		GA88	
	August	October	August	October
	% of dry weight			
Threonine	0.60	0.47	0.72	0.74
Valine	0.71	0.58	0.87	0.95
Methionine	0.22	0.07	0.29	0.26
Isoleucine	0.60	0.49	0.73	0.77
Leucine	1.14	0.86	1.40	1.40
Phenylalanine	0.75	0.60	0.94	0.94
Lysine	0.79	0.62	0.88	0.99
Total as % of dry weight	4.81	3.69	5.83	6.05
Total as % of protein	35.77	34.29	37.64	36.82

TABLE 4 Comparisons of essential amino acid contents (tryptophan excluded) in six hybrid poplar clones and some common agricultural crops

Source	Essential amino acid content	
	% of protein	% of dry weight
Poplar leaves (collected August 13/74)		
Populus x GA88	37.6	5.82
" x DN1	38.6	5.82
" x DN20	41.9	5.37
" x I-45/51	35.8	4.81
" x DN17	35.5	4.41
Populus x *Gelrica* leaves (Siren *et al* 1970)	43.1	14.0
Agricultural crops (Siren *et al* 1970)		
Soya	37.0	15
Peanut	26.4	8
Peas	35.4	7
Oats	32.0	5
Maize	40.8	4
Wheat	28.9	3
Rice	32.6	2

Table 4 summarizes and compares the EAA content of August leaves with data given by Siren *et al* (1970) for *P.* x *euramericana* cl. *Gelrica* and some selected agricultural crops. The quality (EAA composition) of the protein in poplars compares very favourably with most of the common agricultural crops. The quantity of EAA, however, is somewhat lower than in soya, peas, and peanuts, although in Siren's study, Gelrica compared very favourably with soya. Possibly optimum selection and culture of hybrids would improve the relative EAA yield. Nitrogen fertility could be of utmost importance in maintaining and improving the EAA content of tissues.

DISCUSSION

The use of total above-ground poplar biomass could take many forms. The wood-fibre portion could be used either for production of paper or fibre-board products, or for roughage, or processed for animal feed. The "technical foliage" (leaves plus small branches) is a source of food and protein. The raw or ensiled foliage could be used as fodder for livestock, and replace, at least partly, the widely used grain crops. Protein or amino acid concentrates could be extracted from pressed-leaf juice (Pirie 1971). The residue could be used as a nitrogen-source fodder or as an energy source for single-cell (microbial) protein production. Studies are in progress to establish technical procedures and to determine the utility of possible products.

Depending on the desired management and product objectives, the plantation could be directed towards food production alone or towards integrated food and fibre materials. Several options for harvesting are being studied. For example, the multiple-use aspect could be served by combing-off the technical foliage in late summer (ie. defoliation) or by harvesting the whole above-ground biomass in early fall and separating technical foliage and stemwood for proper uses. When green protein-rich mass is desired the sprouts might be harvested earlier in the summer with a view to obtaining a potential second harvest of resprouts in the autumn. This latter option would greatly depend on the resprouting and survival of the stools after summer cutting.

With any intensive-utilization option there will be a depletion of the site's nutrient capital if elements removed with the harvested plants are not returned via fertilization. Studies are now being made of the biomass productivity, the associated elemental drain and the status of the nutrients in the soil in order to describe their interactions.

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